Science You Can Use

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Dear Science: The same face of the Moon always faces the Earth. That seems like an almost impossible coincidence. Is it? -- Buck R.

Dear Buck: To close approximation, the time it takes the Moon to make one orbit of the Earth (called the Moon's "orbital period") is equal to the time it takes the Moon to rotate once on its own axis (called the moon's "rotational period") . Let's call this phenomenon "orbital/rotational synchronization", or "ORS" for short.

Under what conditions can ORS lead to the Moon always having the same face to the Earth? To answer this question, let's first look at a highly simplified case, then see how what the simplified case tells us about ORS in actual planetary bodies.

Imagine that instead of being roughly a sphere the Moon

a. is a metal bar
b. half the length of the bar is made of iron and the other half is made of aluminum
c. the bar rotates on an axis that is exactly in the middle of the bar and the axis forms a right angle with the plane of the bar's orbit about the Earth
d. the orbit of the bar is a circle about the center of the Earth, i.e., the center of the bar always the same distance from the Earth.
e. the bar initially makes more than one, or less than one, complete rotation on its axis during the time the bar makes one orbit about Earth

(Sketching what's described in (a) – (e) will help you to visualize what they mean.)

(c) and (d) closely approximate the relationship between the real Moon's orbit and the orientation of the real Moon's axis of rotation with respect to the plane of its orbit.

Newton's law of gravity tells us that the Earth's gravitational pull on the bar increases with mass. Because the half of the bar that is made of iron has more mass than the half of the bar that is made of aluminum, the Earth exerts a stronger pull on the iron half than on the aluminum half.

(e) says we have to consider two cases: a case in which the bar initially makes more than one, and a case in which the bar makes less than one, rotation on its axis during the time it takes the bar to make one orbit around the Earth. Let's analyze these in turn.

Case 1. Suppose that initially, the bar makes more than one complete rotation on its axis during the time it takes the bar to make one orbit around the Earth. Because the iron half of the bar has more mass than the aluminum half, the Earth's gravitational pull on the iron half of the bar will tend to pull more on the iron half of the bar than the aluminum half, thus decreasing the rotational speed of the bar. Put another way, gravity will tend to slow the bar's rotation, making it more likely that the iron end of the bar points toward Earth.

Case 2. Suppose that initially, the time it takes the bar to make one complete rotation on its axis is longer than the time it takes the bar to complete one orbit about the Earth. The Earth's gravitational pull on the iron half will tend to attract the iron half to point toward the Earth, that is, the rotational speed of the bar will tend to increase so that the iron half points toward Earth.

Over enough time under these conditions, the rotation of the bar will slow down (or speed up, depending on Case 1 or Case 2) in such a way that the iron half of the bar always points toward Earth. By definition, the result is ORS. Gravitationally induced ORS is often called "gravitational locking", or just "locking".

Now of course the Moon is not shaped like a bar, and it is not half iron and half aluminum. But it turns out that the half of the Moon that faces the Earth has more mass than other half. Thus, in the same way the Earth/bar system evolves to ORS, the half of the Moon that has more mass will evolve to ORS with Earth, i.e., the face of the more massive half of the Moon will, after sufficient time, always face Earth.

For further information, see John Lewis, *Physics and Chemistry of the Solar System,* Academic Press, 2012, especially pp. 242-243.

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